

(12) **UK Patent Application** (19) **GB** (11) **2 348 197** (13) **A**

(43) Date of A Publication 27.09.2000

(21) Application No 0000695.7

(22) Date of Filing 14.01.2000

(30) Priority Data

(31) 19913227 (32) 23.03.1999 (33) DE

(71) Applicant(s)

Carl-Zeiss-Stiftung
(Incorporated in the Federal Republic of Germany)
Schott Glas, Hattenbergstrasse 10, D-55122 Mainz,
Federal Republic of Germany

(72) Inventor(s)

Christian Kunert
Johannes Rottgers
Roland Leroux
Peter Brix

(74) Agent and/or Address for Service

Marks & Clerk
Alpha Tower, Suffolk Street Queensway,
BIRMINGHAM, B1 1TT, United Kingdom

(51) INT CL⁷

C03C 3/091 4/00

(52) UK CL (Edition R)

C1M MAL M101 M150 M157 M159 M171 M179 M214
M290
U1S S1787

(56) Documents Cited

JP 640087529 A
WPI abstract 1975-74324W & DE002419724A

(58) Field of Search

UK CL (Edition R) C1M MAG MAL
INT CL⁷ C03C 3/091
ONLINE: WPI,EPODOC,JAPIO

(54) Abstract Title

Use of thermal shock-resistant glass for beverage containers

(57) A glass having the composition (in % by weight, based on oxide) SiO₂ 78.5 - 79.5, B₂O₃ 13.0 - 14.0, Al₂O₃ 2.0 - 3.0, Na₂O 4.5 - 5.5, K₂O 0 - 0.6 is used for the production of thermal shock-resistant beverage containers, in particular teapots, coffee machine jugs and baby-milk bottles.

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**Use of a glass for thermal shock-resistant beverage
containers**

The invention relates to the use of a glass for the production of thermal shock-resistant beverage containers.

Glass containers which are intended for the preparation or storage of hot beverages, such as, for example, coffee machine jugs, teapots and baby-milk bottles, must be made of glasses which have high thermal shock resistance, which arises from a low coefficient of thermal expansion and a low modulus of elasticity, and good chemical resistance. Such vessels are therefore made of borosilicate glasses, as used for laboratory equipment.

The group of borosilicate glasses has been known for some time. For example, German patent specifications DE 588 643 and DE 679 155 disclose heat-resistant glasses made from SiO_2 , Al_2O_3 , B_2O_3 and R_2O , in particular from (% by weight) $\geq 80 \text{ SiO}_2$, 13 B_2O_3 , 2 Al_2O_3 and 4 Na_2O , having a coefficient of expansion $\alpha_{20/300}$ of $\leq 3.4 \cdot 10^{-6}/\text{K}$. Borosilicate glasses for laboratory applications must meet strict requirements and satisfy the DIN ISO 3585 standard on "Borosilicate glass 3.3", i.e. must have, inter alia, a coefficient of linear thermal expansion $\alpha_{20/300}$ of between 3.2 and $3.4 \times 10^{-6}/\text{K}$.

Owing to their composition, the known glasses which comply with the above standard have very high melting points. In addition, they can only be produced with comparatively low melting capacities. While conventional container glasses based on soda-lime glass are produced in equipment having melting capacities of up to 450 tonnes of glass per day with maximum temperatures of below 1450°C , melting capacities of less than 60 tonnes of glass per day are usual for

borosilicate glasses 3.3 and melting points of at least 1650°C are necessary. The reason for the low melting capacities is firstly that troughs for larger throughputs cannot be built since no materials are available for constructing, for example, large domes for the high temperatures. In the case of fully electric troughs, uniform heating cannot be guaranteed in the case of relatively large troughs. Owing to the smaller equipment and higher melting points, the production of these borosilicate glasses requires significantly more energy than does the production of soda-lime glasses. This, together with the more expensive raw materials for borosilicate glasses, results in higher glass prices for borosilicate glasses 3.3.

Against the background of increasing pressure on industry to save energy and to reduce production costs overall, the use of very melting energy-intensive borosilicate glass 3.3 can no longer be justified for products which do not have to satisfy the very strict requirements made of laboratory equipment. At the same time, however, the energy saving and productivity increase achieved must not be negated by plant down times during the glass change on production of an alternative glass in the same melting equipment.

The object of the invention is therefore to find a glass which requires less melting energy, i.e. a glass which has low melting and working points, has adequate thermal shock resistance for the production of heat-resistant beverage containers and in addition has high chemical resistance similar to that of borosilicate glasses 3.3.

This object is achieved by using a glass as described in Patent Claim 1.

A glass from the narrow composition range (in % by

weight, based on oxide) of

SiO ₂	78.5 - 79.5
B ₂ O ₃	13.0 - 14.0
Al ₂ O ₃	2.0 - 3.0
Na ₂ O	4.5 - 5.5
K ₂ O	0 - 0.6

owing to the balanced ratio of the components present, combines properties which were hitherto regarded as uncombinable with one another.

The relatively high SiO₂ content facilitates the low thermal expansion; at even higher contents, the improved melting properties, expressed by the reduced melting point, would not be achieved.

Al₂O₃ in the stated amounts counters separation of the glass, which would result in a reduction in the chemical resistance and in haze. At least 2.0% by weight are necessary for this purpose. Higher contents than 3.0% by weight cannot be combined with the other requirements of a glass since the melting point would rise to an impermissible extent.

The relatively high content of Na₂O causes the reduction in the melting point. This action can be reinforced further by a K₂O content of up to 0.6% by weight.

The narrow range mentioned for the B₂O₃ content, together with the alkali metal oxide(s), produces the low melting point. Higher B₂O₃ contents result in a significant increase in the raw materials costs, which would negate the savings achieved by the lower melting energy requirement. Lower contents are likewise not possible for the intended purpose since this would result in a rise in the melting point. In principle, a lowering of the melting point could be achieved by a

further increase in the alkali metal content, but the stated upper limits for Na_2O and K_2O must not be exceeded in order to satisfy the high demands on chemical resistance. With a lower alkali metal content than the stated lower limit, the lower melting point cannot be achieved owing to the restriction in the B_2O_3 content.

In order to improve the glass quality, the glass can also contain conventional fining agents, such as As_2O_3 , Sb_2O_3 or chlorides (NaCl , KCl) in conventional amounts. It is furthermore possible for the glass to contain up to a total of 0.5% by weight of further oxides, such as, for example, MgO , CaO or other oxides which are introduced into the glass composition via impurities and which have no interfering effect, i.e. do not influence the suitability for the stated use. It is also possible for decolorants, such as, for example, Er_2O_3 or CoO , to the present.

The glass used in accordance with the invention has a working point V_A , i.e. the temperature at a viscosity of 10^4 dPas, of $\leq 1220^\circ\text{C}$. This temperature is below that of the commercially available borosilicate glass 3.3 having the composition (in % by weight) 80.1 SiO_2 , 13.0 B_2O_3 , 2.5 Al_2O_3 , 3.5 Na_2O , 0.6 K_2O , 0.3 NaCl (Comparative Example V) with a working point V_A of 1250°C . The improvement is even clearer on comparison of the temperatures at a viscosity of 10^3 dPas (T_3), which is of greater relevance for melting of the glass. For the glass according to the invention, this temperature is at most 1460°C , while it is 1530°C for V.

The figures document the ease of melting of the glass. It enables the maximum melting point to be lowered by about 30°C in industrial melting units with a simultaneous increase in the production capacity by about 10%, in each case compared with glass V.

It is known that the chemical resistance, in particular the hydrolytic and acid resistance, of a glass whose composition is varied by reducing the SiO_2 content and increasing the alkali metal content so that the glass becomes "softer", i.e. its melting point is reduced, is impaired.

Surprisingly, and with great importance for the object to be achieved, this was not the case in the present invention. Instead, the chemical resistance of the glass is very high. The glass has both a hydrolytic resistance H in accordance with DIN ISO 719 in hydrolytic class 1 and an acid resistance S in accordance with DIN 12 116 in acid class 1. Its caustic lye resistance L in accordance with DIN ISO 659, in lye class 2, is just as good as for borosilicate glass 3.3. This is particularly surprising inasmuch as the glass, compared with glass V, contains more Na_2O , which is known for its disadvantageous effect on the chemical resistance, and no additional components, such as, for example, CaO , for improving the hydrolytic and acid resistance.

The glass has a coefficient of linear thermal expansion $\alpha_{20/300}$ of between 3.5 and $3.7 \times 10^{-6}/\text{K}$ and a modulus of elasticity E of ≤ 65 GPa. With these properties, the glass has a low specific thermal stress ϕ , which is given by $\phi = (E \times \alpha)/(1 - \mu)$, where μ is the Poisson number, which hardly changes at all with the glass composition and can be assumed to be a constant value of 0.2. Thus, the glass according to Working Example A (composition see below) has a specific thermal stress $\phi = 0.3$ MPa/K, while ϕ for conventional soda-lime container glass ($\alpha = 9.0 \times 10^{-6}/\text{K}$, $E = 70$ GPa) is 0.78 MPa/K.

The specific thermal stress is a measure of the thermal shock resistance. With this low specific thermal stress, the glass has a sufficiently high thermal shock

resistance for it to be eminently suitable for the described use as beverage container glass, in particular for baby-milk bottles, coffee machine jugs and teapots, with the thermal shocks that occur in these applications.

Working example:

The Table shows a glass from the composition range according to the invention (Working Example A) and a Comparative Example V, with the respective compositions (% by weight) and the essential properties.

After the raw materials had been weighed out and mixed thoroughly, the glasses were melted in an electrically heated melting unit at temperatures of up to 1620°C (A) or 1650°C (V).

Table: Composition (in % by weight) and essential properties of a working example (A) and a comparative example (V):

	A	V
SiO ₂	79.0	80.1
B ₂ O ₃	13.45	13.0
Al ₂ O ₃	2.4	2.5
Na ₂ O	4.85	3.5
K ₂ O	-	0.6
NaCl	0.3	0.3
$\alpha_{20/100}$ [10 ⁻⁶ /K]	3.6	3.3
Glass transition temperature T _g [°C]	530	520
V _A [°C]	1205	1250
T ₃ [°C]	1440	1530
E [GPa]	64	63
H [class]	1	1
S [class]	1	1
L [class]	2	2

The glass combines high chemical resistance and high

thermal shock resistance, especially low thermal expansion, with good melting properties, especially a low working point. It is thus superior to borosilicate glasses 3.3 for applications which, although requiring a relatively high thermal shock resistance of the glasses, do not need the glasses to comply with DIN ISO 3585, since they can be produced at lower melting points and with higher melting capacities.

The fact that the glass has a similar composition to borosilicate glasses 3.3, in particular that it preferably contains no additional components, is of great advantage. Thus, it can be produced alternately with the borosilicate glass 3.3 in the same production equipment, and only low remelting times occur. The increased productivity of the glass melting equipment with this glass reduces the production costs of thermal shock-resistant beverage containers while retaining the quality of the properties relevant to this use.

CLAIMS

1. The use of a glass having the composition (in % by weight, based on oxide) SiO_2 78.5 - 79.5, B_2O_3 13.0 - 14.0, Al_2O_3 2.0 - 3.0, Na_2O 4.5 - 5.5, K_2O 0 - 0.6, and, optionally, one or more fining agents, for the production of thermal shock-resistant beverage containers.
2. The use according to claim 1 for the production of teapots, coffee machine jugs and baby-milk bottles.
3. The use according to claim 1 or 2, where the glass additionally contains up to 0.5% by weight of non-interfering oxides.
4. The use according to any one of claims 1 to 3, where the glass has a coefficient of linear thermal expansion $\alpha_{20/300}$ of between 3.5 and $3.7 \times 10^{-6}/\text{K}$, a working point V_A of $\leq 1220^\circ\text{C}$, a modulus of elasticity of ≤ 65 GPa, a hydrolytic resistance in accordance with DIN ISO 719 in hydrolytic class 1, an acid resistance S in accordance with DIN 12 116 in acid class 1, and a caustic lye resistance L in accordance with DIN ISO 659 in lye class 2 (Laugenklasse 2).
5. The use as claimed in claim 1, wherein the glass is substantially as hereinbefore described in working example (A).
6. A thermal shock-resistant beverage containing formed of a glass as defined in any one of claims 1, 3, 4, and 5.